

## REPORT DOCUMENTATION PAGE

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13. ABSTRACT (Maximum 200 words) The type of thermo-mechanical processing, often referred to as "grain-boundary engineering," involves repeated steps of cold work followed by annealing for re-crystallization. This has been shown in the past to result in an increase of special grain boundaries in FCC alloys such as stainless steels, meaning grain boundaries having a low value of the Sigma parameter, which is the inverse of the concentration of coincident sites on the coincident-site lattice across the boundary. Such boundaries have been shown to improve the resistance of alloys to intergranular stress corrosion cracking and creep rupture, for example. The investigation was based on the idea that dynamic embrittlement represents the percolation of intergranular decohesion along the grain boundaries and that in 1N718 this is caused by stress-driven diffusive penetration of oxygen along boundaries having a high oxygen diffusivity. Thus, the starting hypothesis was that a decrease in the concentration of random boundaries, i.e., those with comparatively large free volume, would retard dynamic embrittlement. This kind of experiment had never been done before in this area or on such a complex alloy as IN718. The experiments entailed not only the processing, but also the analysis of the grain-boundary-character distribution using orientation-imaging microscopy, before carrying out the mechanical testing at 650t in an environmentally controlled chamber. The results showed that this processing substantially retarded the cracking, and this now will lead the way toward possible improvements in the serviceability of this important alloy in the field of gas turbines and aircraft engines.			
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## Final Report on AFOSR grant No.F49620-02-1-0011

This grant provided partial support for Dr. Ulrich Krupp during his one-year stay at the University of Pennsylvania as a visiting scientist. Dr. Krupp has now returned to his permanent position at the University of Siegen in Germany.

During his stay, Dr. Krupp carried out work in two areas in our program on dynamic embrittlement of the nickel-base superalloy IN718. In the first area, he was able to show that the thermo-mechanical treatment known as grain-boundary engineering is effective in reducing the tendency for this kind of cracking in IN718. Dynamic embrittlement in this alloy involves the penetration of grain boundaries by surface-adsorbed oxygen as the result of the application of a tensile stress, and the cracking of these boundaries at a rate dependent on the diffusion of oxygen into the boundaries at the crack tip. The GBE processing entails repeated cold work and recrystallizing anneals such that the fraction of grain boundaries having special orientations is increased. In this case it was mainly the  $\Sigma 3$  boundaries, in the coincident-site-lattice nomenclature. The sigma value is the reciprocal of the density of lattice sites that are coincident when both lattices of adjacent grains are superimposed. Since  $\Sigma 3$  boundaries are rather coherent and have minimal free volume, it is expected that the diffusion coefficient of any solute element would be greatly reduced.

Dr. Krupp showed that four GBE cycles had the effect of increasing the fraction of  $\Sigma 3$  boundaries to about 1/3 of the total and of significantly increasing the resistance to dynamic embrittlement. This resistance came by virtue of the fact that the number of grain boundaries that remained uncracked was increased, and the brittle crack had more difficulty percolating through the network of boundaries. In this preliminary work, the GBE process was not optimized for this material, so it is probable that further work would result in further improvement in the resistance to cracking.

The significance of this work is that dynamic embrittlement is the determining factor in the lifetime of some important components of jet engines, which are heavy users of this alloy. Any treatment that increases the resistance to dynamic embrittlement has the potential for life extension of such components. A paper that describes this work is in press in the journal Materials Science and Engineering A and is appended to this report.

In the second area, Dr. Krupp initiated our work on bicrystals of IN718 fabricated by diffusion bonding of single crystals that we had obtained from Howmet Corporation. He showed that a random boundary cracks much faster than a  $\Sigma 5$  CSL boundary, again indicating the importance of intergranular diffusivity, since the free volume of a random boundary is significantly greater

than in the  $\Sigma 5$  boundary. In addition, the random boundary was shown to crack in a continuous way, unlike the boundaries in polycrystals, which crack discontinuously because of the constraint imposed by surrounding non-cracking boundaries. This work was the first step in a larger program to study bicrystals that is now in progress. The results are described in a review paper prepared by Dr. Krupp for International Materials Reviews, a copy of which is also appended to this report, as is a third paper given in an international conference in Rio de Janeiro.